Appendix C
Testing Technologies

Table C-1. Non-Invasive Assessment Technologies

Applications	Strengths	Weaknesses	Typical Costs[1]
Infrared Thermography (IR/T)			
Locates buried USTs. • Locates buried leaks from USTs. • Locates buried sludge pits. • Locates buried nuclear and nonnuclear waste. • Locates buried oil, gas, chemical and sewer pipelines. • Locates buried oil, gas, chemical and sewer pipeline leaks. • Locates water pipelines. • Locates water pipeline leaks. • Locates seepage from waste dumps. • Locates subsurface smoldering fires in waste dumps. • Locates unexploded ordinance on hundreds or thousands of acres. • Locates buried landmines.	• Able to collect data on large areas very efficiently. (Hundreds of acres per flight) • Able to collect data on long cross country pipelines very efficiently (300-500 miles per day.) • Low cost for analyzed data per acre unit. • Able to prescreen and eliminate clean areas from further costly testing and unneeded rehabilitation. • Able to fuse data with other techniques for even greater accuracy in more situations. • Able to locate large and small leaks in pipelines and USTs. (Ultrasonic devices can only locate small, high pressure leaks containing ultrasonic noise.) • No direct contact with objects under test is required. (Ultrasonic devices must be in contact with buried pipelines or USTs.) • Has confirmed anomalies to depths greater than 38 feet with an accuracy of better than 80%. • Tests can be performed during both daytime and nighttime hours. • Normally no inconvenience to the public. •	• Cannot be used in rainy conditions. • Cannot be used to determine depth or thickness of anomalies. • Cannot determine what specific anomalies are detected. • Cannot be used to detect a specific fluid or contaminant, but all items not native to the area will be detected.	• Depends upon volume of data collected and type of targets looked for. • Small areas <1 acre: $1,000-$3,500. • Large areas>1,000 acres: $10 - $200 per acre.
Ground Penetrating Radar (GPR)			
• Locates buried USTs. • Locates buried leaks from USTs. • Locates buried sludge pits. • Locates buried nuclear and nonnuclear waste. • Locates buried oil, gas, chemical and sewer pipelines. • Locates buried oil and chemical pipeline leaks. • Locates water pipelines. • Locates water pipeline leaks. • Locates seepage from waste dumps. • Locates cracks in subsurface strata such as limestone.	• Can investigate depths from 1 centimeter to 100 meters+ depending upon soil or water conditions. • Can locate small voids capable of holding contamination wastes. • Can determine different types of materials such as steel, fiberglass or concrete. • Can be trailed behind a vehicle and travel at high speeds.	• Cannot be used in highly conductive environments such as salt water. • Cannot be used in heavy clay soils. • Data are difficult to interpret and require a lot of experience.	• Depends upon volume of datacollected and type of targets looked for. • Small areas <1 acre: $3,500 - $5,000 • Large areas > 10 acres: $2,500 - $3,500 per acre

Non-Invasive Assessment Technologies Continued			
Electromagnetic Offset Logging (EOL)			
• Locates buried hydrocarbon pipelines • Locates buried hydrocarbon USTs. • Locates hydrocarbon tanks. • Locates hydrocarbon barrels. • Locates perched hydrocarbons. • Locates free floating hydrocarbons. • Locates dissolved hydrocarbons. • Locates sinker hydrocarbons. • Locates buried well casings.	• Produces 3D images of hydrocarbon plumes. • Data can be collected to depth of 100 meters. • Data can be collected from a single, unlined or nonmetal lined well hole. • Data can be collected within a 100 meter radius of a single well hole. • 3D images can be sliced in horizontal and vertical planes. • DNAPLs can be imaged.	• Small dead area around well hole of approximately 8 meters. • This can be eliminated by using 2 complementary well holes from which to collect data.	• Depends upon volume of data collected and type of targets looked for. • Small areas < 1 acre: $10,000 - $20,000 • Large areas > 10 acres: $5,000 - $10,000 per acre
Magnetometer (MG)			
• Locates buried ferrous materials such as barrels, pipelines, USTs, and buckets.	• Low cost instruments can be be used that produce results by audio signal strengths. • High cost instruments can be used that produce hard copy printed maps of targets. • Depths to 3 meters. 1 acre per day typical efficiency in data collection.	• Non-relevant artifacts can be confusing to data analyzers. • Depth limited to 3 meters.	• Depends upon volume of data collected and type of targets looked for. • Small areas < 1 acre: $2,500 - $5,000 • Large areas > 10 acres: $1,500 -$2,500 per acre

[1] Cost based on case study data in 1997 dollars.

Table C-2. Soil and Subsurface Sampling Tools

	Media			
Technique/Instrumentation	Soil	Ground Water	Relative Cost per Sample	Sample Quality
Drilling Methods				
Cable Tool	X	X	Mid-range expensive	Soil properties will probably be altered
Casing Advancement	X	X	Most expensive	Soil properties will likely be altered
Direct Air Rotary with Rotary Bit Downhole Hammer	X	X	Mid-range expensive	Soil properties will probably be altered
Direct Mud Rotary	X	X	Mid-range expensive	Soil properties may be altered
Directional Drilling	X	X	Most expensive	Soil properties may be altered
Hollow-Stem Auger	X	X	Mid-range expensive	Soil properties may be altered
Jetting Methods	X	X	Least expensive	Soil properties may be altered
Rotary Diamond Drilling	X	X	Most expensive	Soil properties may be altered
Rotating Core	X		Mid-range expensive	Soil properties may be altered
Solid Flight and Bucket Augers	X	X	Mid-range expensive	Soil properties will likely be altered
Sonic Drilling	X	X	Most expensive	Soil properties will probably be unaltered
Split and Solid Barrel	X		Least expensive	Soil properties may be altered
Thin-Wall Open Tube	X		Mid-range expensive	Soil properties will probably be unaltered
Thin-Wall Piston/l Specialized Thin Wall	X		Mid-range expensive	Soil properties will probably be unaltered
Direct Push Methods				
Cone Penetrometer	X	X	Mid-range expensive	Soil properties may be altered
Driven Wells		X	Mid-range expensive	Soil properties may be altered
Hand-Held Methods				
Augers	X	X	Least expensive	Soil properties may be altered
Rotating Core	X		Mid-range expensive	Soil properties may be altered
Scoop, Spoons, and Shovels	X		Least expensive	Soil properties may be altered
Split and Solid Barrel	X		Least expensive	Soil properties may be altered
Thin-Wall Open Tube	X		Mid-range expensive	Soil properties will probably be unaltered
Thin-Wall Piston Specialized Thin Wall	X		Mid-range expensive	Soil properties will probably be unaltered
Tubes	X		Least expensive	Soil properties will probably be unaltered

Table C-3. Groundwater Sampling Tools

Technique/Instrumentation	Contaminants[1]	Relative Cost per Sample	Sample Quality
Portable Groundwater Sampling Pumps			
Bladder Pump	SVOCs, PAHs, metals	Mid-range expensive	Liquid properties will probably be unaltered
Gas-Driven Piston Pump	SVOCs, PAHs, metals	Most Expensive	Liquid properties will probably be unaltered by sampling
Gas-Driven Displacement Pumps	SVOCs, PAHs, metals	Least expensive	Liquid properties will probably be unaltered by sampling
Gear Pump	SVOCs, PAHs, metals	Mid-range expensive	Liquid properties may be altered
Inertial-Lift Pumps	SVOCs, PAHs, metals	Least expensive	Liquid properties will probably be unaltered
Submersible Centrifugal Pumps	SVOCs, PAHs, metals	Most expensive	Liquid properties may be altered
Submersible Helical-Rotor Pump	SVOCs, PAHs, metals	Most expensive	Liquid properties may be altered
Suction-Lift Pumps (peristaltic)	SVOCs, PAHs, metals	Least expensive	Liquid properties may be altered
Portable Grab Samplers			
Bailers	VOCs, SVOCs, PAHs, metals	Least expensive	Liquid properties may be altered
Pneumatic Depth-Specific Samplers	VOCs, SVOCs, PAHs, metals	Mid-range expensive	Liquid properties will probably be unaltered
Portable In Situ Groundwater Samplers/Sensors			
Cone Penetrometer Samplers	VOCs, SVOCs, PAHs, metals	Least expensive	Liquid properties will probably be unaltered
Direct Drive Samplers	VOCs, SVOCs, PAHs, metals	Least expensive	Liquid properties will probably be unaltered
Hydropunch	VOCs, SVOCs, PAHs, metals	Mid-range expensive	Liquid properties will probably be unaltered
Fixed In Situ Samplers			
Multilevel Capsule Samplers	VOCs, SVOCs, PAHs, metals	Mid-range expensive	Liquid properties will probably be unaltered
Multiple-Port Casings	VOCs, SVOCs, PAHs, metals	Least expensive	Liquid properties will probably be unaltered
Passive Multilayer Samplers	VOCs	Least expensive	Liquid properties will probably be unaltered

Bold Most commonly used field techniques
VOCs Volatile Organic Carbons
SVOCsSemivolatile Organic Carbons
PAHs Polyaromatic Hydrocarbons

Table C-4. Sample Analysis Technologies

		Media						
Technique/ Instrumentation	**Analytes**	**Soil**	**Ground Water**	**Gas**	**Relative Detection**	**Relative Cost per Analysis**	**Application****	**Produces Quantitative Data**
Metals								
Laser-Induced Breakdown Spectrometry	Metals	X			ppb	Least expensive	Usually used in field	Additional effort required
Titrimetry Kits	Metals	X	X		ppm	Least expensive	Usually used in laboratory	Additional effort required
Particle-Induced X-ray Emissions	Metals	X	X		ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
Atomic Adsorption Spectrometry	Metals	X*	X	X	ppb	Most expensive	Usually used in laboratory	Yes
Inductively Coupled Plasma--Atomic Emission Spectroscopy	Metals	X*	X	X	ppb	Most expensive	Usually used in laboratory	Yes
Field Bioassessment	Metals	X	X			Most expensive	Usually used in field	No
X-Ray Fluorescence	Metals	X	X	X	ppm	Least expensive	Laboratory and field	Yes (limited)
PAHs, VOCs, and SVOCs								
Laser-Induced Fluorescence (LIF)	PAHs	X	X		ppm	Least expensive	Usually used in field	Additional effort required
Solid/Porous Fiber Optic	VOCs	X*	X	X	ppm	Least expensive	Immediate, can be used in field	Additional effort required
Chemical Calorimetric Kits	VOCs, SVOCs, PAHs	X	X		ppm	Least expensive	Can be used in field, usually used in laboratory	Additional effort required
Flame Ionization Detector (hand-held)	VOCs	X*	X*	X	ppm	Least expensive	Immediate, can be used in field	No
Explosimeter	VOCs	X*	X*	X	ppm	Least expensive	Immediate, can be used in field	No
Photo Ionization Detector (hand-held)	VOCs, SVOCs	X*	X*	X	ppm	Least expensive	Immediate, can be used in field	No
Catalytic Surface Oxidation	VOCs	X*	X*	X	ppm	Least expensive	Usually used in laboratory	No
Near IR Reflectance/Trans Spectroscopy	VOCs	X			100-1,000 ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
Ion Mobility Spectrometer	VOCs, SVOCs	X*	X*	X	100-1,000 ppb	Mid-range expensive	Usually used in laboratory	Yes

Sample Analysis Technologies (continued)

Technique/ Instrumentation	Analytes	Media: Soil	Media: Ground Water	Media: Gas	Relative Detection	Relative Cost per Analysis	Application**	Produces Quantitative Data
Infrared Spectroscopy	VOCs, SVOCs	X	X	X	100-1,000 ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
Scattering/Absorption Lidar	VOCs	X*	X*	X	100-1,000 ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
FTIR Spectroscopy	VOCs	X*	X*	X	ppm	Mid-range expensive	Laboratory and field	Additional effort required
Synchronous Luminescence/ Fluorescence	VOCs, SVOCs	X*	X		ppb	Mid-range expensive	Usually used in laboratory, can be used in field	Additional effort required
Gas Chromatography (GC) (can be used with numerous detectors)	VOCs, SVOCs	X*	X	X	ppb	Mid-range expensive	Usually used in laboratory, can be used in field	Yes
UV-Visible Spectrophotometry	VOCs	X*	X	X	ppb	Mid-range expensive	Usually used in laboratory	Additional effort required
UV Fluorescence	VOCs	X	X	X	ppb	Mid-range expensive	Usually used in laboratory	Additional effort required
Ion Trap	VOCs, SVOCs	X*	X*	X	ppb	Most expensive	Laboratory and field	Yes
Other								
Chemical Reaction- Based Test Papers	VOCs, SVOCs, Metals	X	X		ppm	Least expensive	Usually used in field	Yes
Immunoassay and Calorimetric Kits	VOCs, SVOCs, Metals	X	X		ppm	Least expensive	Usually used in laboratory, can be used in field	Additional effort required

VOCs Volatile Organic Compounds
SVOCs Semivolatile Organic Compounds (may be present in oil and grease)
PAHs Polyaromatic Hydrocarbons
X* Indicates there must be extraction of the sample to gas or liquid phase
** Samples sent to laboratory require shipping time and usually 14 to 35 days turnaround time for analysis. Rush orders cost an additional amount per sample.